Reprinted from SPIE Vol. 940—Infrared Scene Simulation: Systems, Requirements, Calibration, Devices, and Modeling


# Low Background Infrared Calibration Facility at The National Bureau of Standards*

A.C. Parr, J. Fowler and S. Ebner

The National Bureau of Standards
Radiometric Physics Division
Gaithersburg, Maryland 20899

## ABSTRACT

The National Bureau of Standards (NBS) has accepted the responsibility for constructing a new facility for the calibration of radiometric sources used in low background environments. Along with the facility's development, a program has been started to study the long term needs of the calibration community and to develop appropriate new test and measurement procedures. The facility consists of a large (60 cm dia by 152 cm long) vacuum chamber whose inner volume is maintained at temperatures of less than 20 K. The radiometer is separated from the source by an isothermal wall whose temperature is actively controlled. The cryogenic cooling of the vacuum interior is accomplished by a closed cycle helium refrigerator system which also contributes to the vacuum maintenance. The source volume can accept a cubic source of up to 30 cm on a side provided the aperture is suitably located. A research and development project is underway to develop methodology to characterize optical attenuators over many orders of magnitude and over a broad wavelength range.

## 1. INTRODUCTION

Until early 1985, the Radiometric Physics Division had provided a service to the low background infrared community in the calibration of blackbody sources. This calibration was primarily a measurement of the total power from a blackbody in a geometrically determined arrangement. The apparatus for this calibration had been built up over a number of years from various vacuum and radiometric instruments in the division. With age the apparatus became difficult to maintain and the division management decided that continued efforts on the old apparatus were not cost effective nor technically feasible. A survey was conducted with the help of numerous outside experts which considered the long term needs of calibration activity in the low background infrared. It was a conclusion of this survey that there was a national need for calibration and research activity in the low background infrared. The Department of Defense through the Strategic Defense Command agreed to help fund such an activity to establish a modern Low Background Infrared (LBIR) calibration facility at the National Bureau of Standards (NBS). The building of the facility is nearing completion and the research and development projects are underway.

## 2. FACILITY

Figure 1 shows the layout of the LBIR facility which is located in the basement of the Physics Building at NBS. This location will provide optimal isolation from vibration and also provides a high ceiling to permit adequate space for a clean room environment as well as affording clearance for cryogenic lines and connections. The room is 10 m long and 6.7 m wide and is arranged as shown in figure 1. The closed cycle helium refrigerator expansion unit (refrig.) is situated on the left side of the room. The compressor which drives the expansion unit is located in a special equipment room approximately 100 meters away and is not shown on the diagram. The central portion of the room which contains the apparatus is covered by a class 10,000 clean room. We expect to maintain ultrahigh vacuum conditions in the chamber and hence the surrounding workspace needs to be carefully controlled. The optical benches will allow for placement of lasers and other optical equipment in the calibration and research phases of the project. The calibration chamber has provisions for installing ports for optical input as well as other mechanical and electrical feed-throughs. The storage tank and bottle racks provide for helium reservoirs needed in various stages of the refrigerator's cooling cycle. The room temperature is controlled by the central NBS cooling and heating system and we expect to improve the cleanliness of the supplied conditioned air with additional filters.

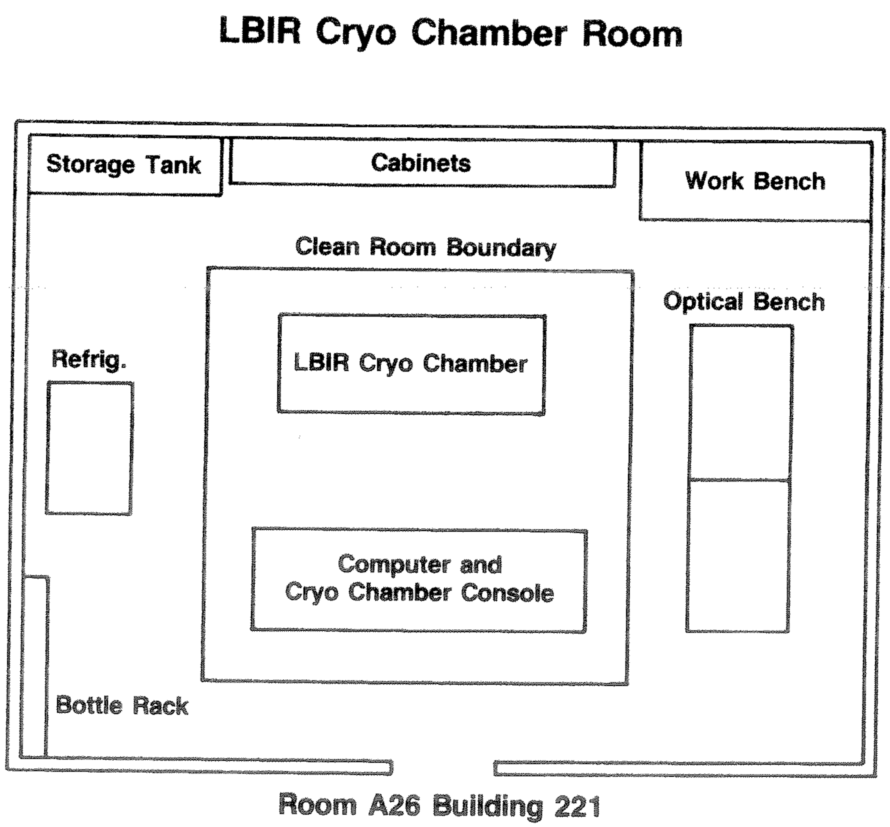


Figure 1) Layout plan for the LBIR laboratory at NBS.

## 3. APPARATUS

Figure 2 shows the apparatus and the expansion engine portion of the cryogenic refrigerator. The salient features of the apparatus are labeled and a partial cutaway view shows the major internal components of the chamber. The auxiliary vacuum shell is for testing and conditioning blackbody sources supplied for calibration to insure that they meet vacuum cleanliness requirements and to test the heating cycle before insertion into the ultrahigh vacuum environment of the calibration chamber. Once the blackbody (BB) source is tested, the auxiliary vacuum shell is removed and the BB source which is mounted off the large flange on the left of the system is inserted into the chamber. The initial vacuum pumpdown is achieved with a turbomolecular pump. Room temperature vacuum maintenance is provided by a vacuum ion pump. Once the vacuum quality is assured the helium refrigerator is started and cooled helium gas is circulated through a network of coils which are brazed onto the two layers of copper shielding internal to the vacuum system. The absolute cryogenic radiometer (ACR) is filled with liquid helium from a separate storage dewar. It is expected that the vacuum pumping and cryogenic cycling time for the system will be several days.

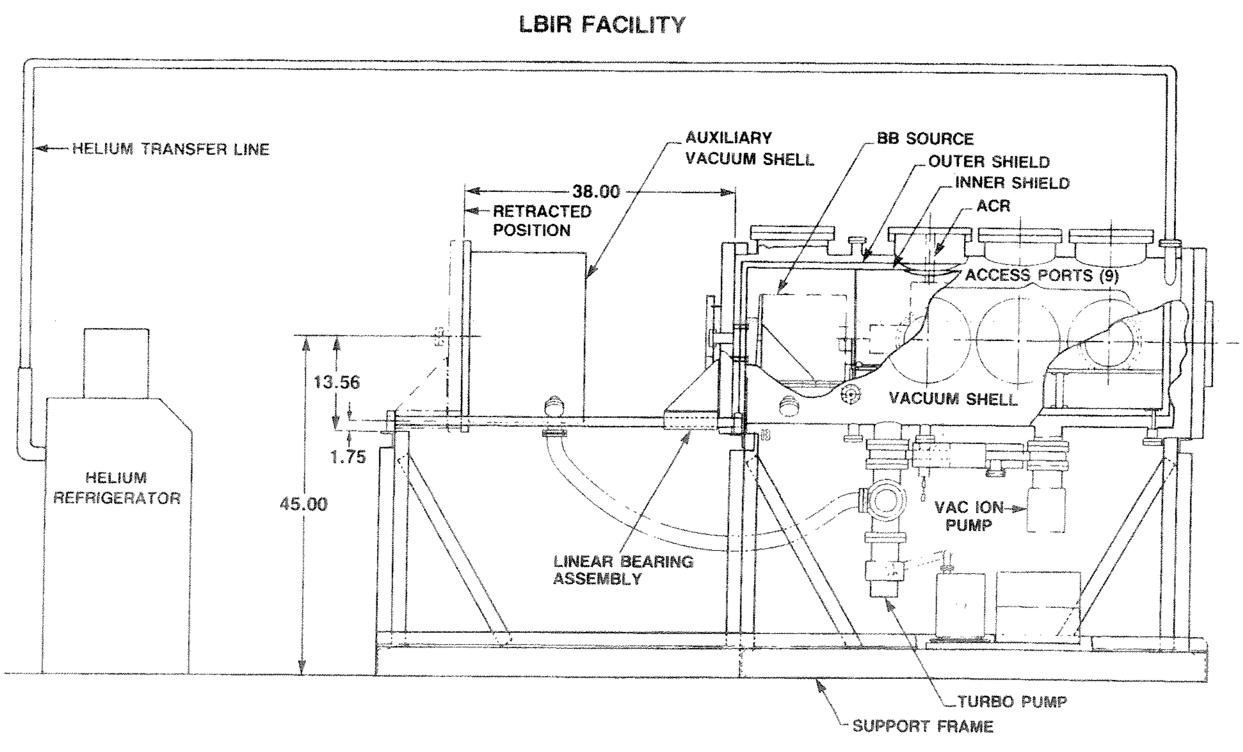


Figure 2) LBIR chamber with partial cutaway which shows the major features of the apparatus. BB Source = BlackBody Source, ACR = Absolute Cryogenic Radiometer.

The entire vacuum shell is constructed of type 304 stainless steel and all the vacuum flanges are sealed with metal seals. Ultra high vacuum materials are used throughout the fabrication of all the internal components of the system. The system features a number of vacuum ports for mechanical and electrical feedthroughs as well as provisions for the addition of optical coupling from the lab to the chamber for future experiments. Appropriate vacuum monitoring gauges and a residual gas analyzer are provided to insure vacuum integrity and cleanliness. It is essential to maintain cleanliness of the overall system for future use of the system in materials characterizations and optical instrument calibration schemes. Consequently, the blackbody sources which are to be calibrated will have to meet system vacuum standards (1).

## 4. RADIOMETER

Figure 3 shows a schematic drawing of the absolute cryogenic radiometer (ACR) which is being constructed for the calibration system (2). The ACR has a resolution of approximately one nanowatt as design criteria. The design considerations suggest that the radiometer will have an inherent accuracy of about 5% at a flux level of 20 nanowatts. Other considerations which involve the shielding, geometry, and operation of the chamber will contribute to the accuracy and precision in manners to be evaluated both experimentally and by modelling of the experiment. The ACR is inserted into the vacuum chamber in any one of three 30.5 cm dia copper seal flanges. The three positions allow for varying the solid angle of collection from a particular blackbody as well as offering the possibility of inserting optical devices between the source and the ACR should that be desired.

A port at the top of the ACR provides access for introducing liquid helium. It is also connected to a pumping system to provide for maintaining the liquid helium at approximately 2 K. The receiver is designed to operate at this temperature and should have a responsivity of approximately 25 K/mW. Carbon resistance thermometers (CRT) will be used to monitor the temperature rise of the receiver cone which will occur upon reception of incident radiation. The receiver cone has a heater fitted on it which can be heated and the temperature response measured for a known amount of electrical power input. Consequently, the radiant power from the blackbody is directly compared with known electrical power in an absolute way and the blackbody characteristics thereby deduced. There is a temperature controlled wall between the source and the radiometer which has apertures which can be varied dependent upon the calibration requirements of a particular source. The receiver cone is to be coated with a material which is to be highly absorbing in the visible and into the 30 to 50 micrometer region of the infrared. Measurements will be made on the ACR to determine these parameters as well as the appropriate modelling of the cone absorption.

## CRYOGENIC RADIOMETER

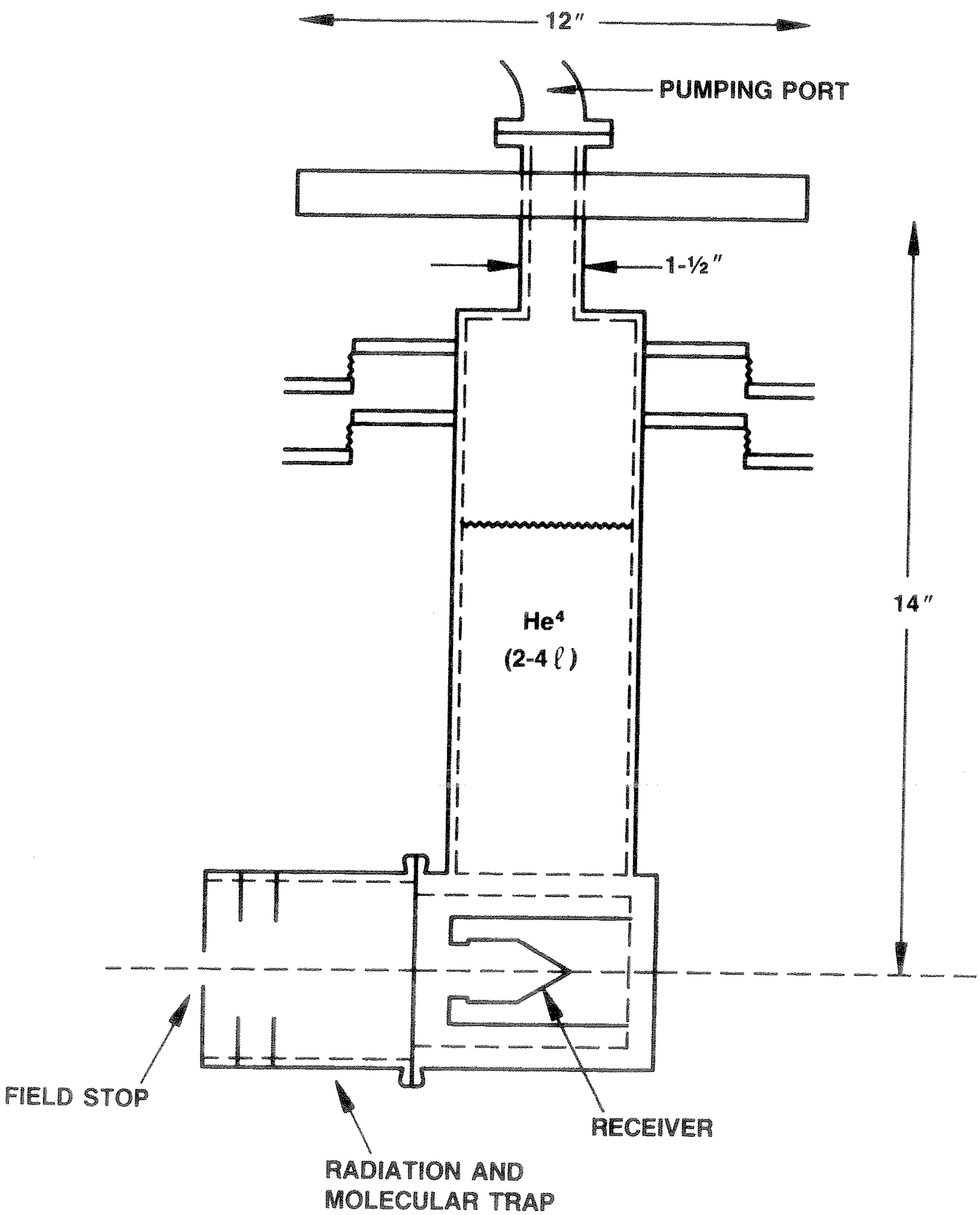


Figure 3) Schematic drawing of the ACR showing the major features as inserted into the facility chamber for calibration purposes.

The liquid helium reservoir of the ACR will make contact with the inner cryoshields with mechanical contacts. This is important to help preserve the helium in the ACR. The electrical leads for the ACR will come out its own flange to provide a single unit which can be placed on any of the large flanges.

## 5. CONTROL SYSTEM

Figure 4 shows the automated control system for the facility. It will be based upon a Compaq Deskpro 386 computer which interfaces with the electronics and electrical control over an IEEE-488 interface (3). The position of the blackbody with respect to the ACR is measured with a highly accurate Kaman proximity sensor and the various temperature sensors relay their information via Lakeshore cryogenic controllers and sensors (4,5). The temperature of the inner shielding is monitored at a number of points and used for evaluation of the refrigeration and for evaluation of the accuracy and reliability of the calibration. Status of the entire system will be displayed continuously and the ACR control function and calibration data will be taken by the same computer. Where appropriate and required the computer can be used to provide control signals for the blackbody sources being calibrated.

The isothermal wall is actively heated and its temperature monitored to maintain the temperature to within $\pm$ 5mK/min. This will help minimize the background fluctuations as measured at the ACR. The surface of the isothermal wall will be coated with a low emissivity material. The ACR control and sequencing will be done by the same Compaq computer over interfaces supplied by the manufacturer.

## 6. OPERATION

It is anticipated that the blackbodies being calibrated will have a determined emissivity and have a known geometry. It will be up to the users of the calibration service to provide the geometric information on their source to NBS so that it can be utilized in the calibration process. If the parameters are unknown it will require extra effort and cost on the part of the calibration service to determine the necessary data. The user will supply the electronics necessary to run their blackbody as well as any mounting hardware particular to their device. The initial calibration activity will be comprised of determination of irradiance of the source at temperature settings desired and specified by the user.

The longer term goal of the calibration effort is to supply other information about the blackbody such as spectral radiance and the possible effects of diffraction on the output as employed by the user. Additionally, it has become clear that it might be useful to provide a calibration for some optical attenuators used in some of the facilities. We expect to be able to either directly perform this measurement service or provide calibrated attenuators over a large dynamic range for intercomparison purposes. To this end we have developed laser heterodyne

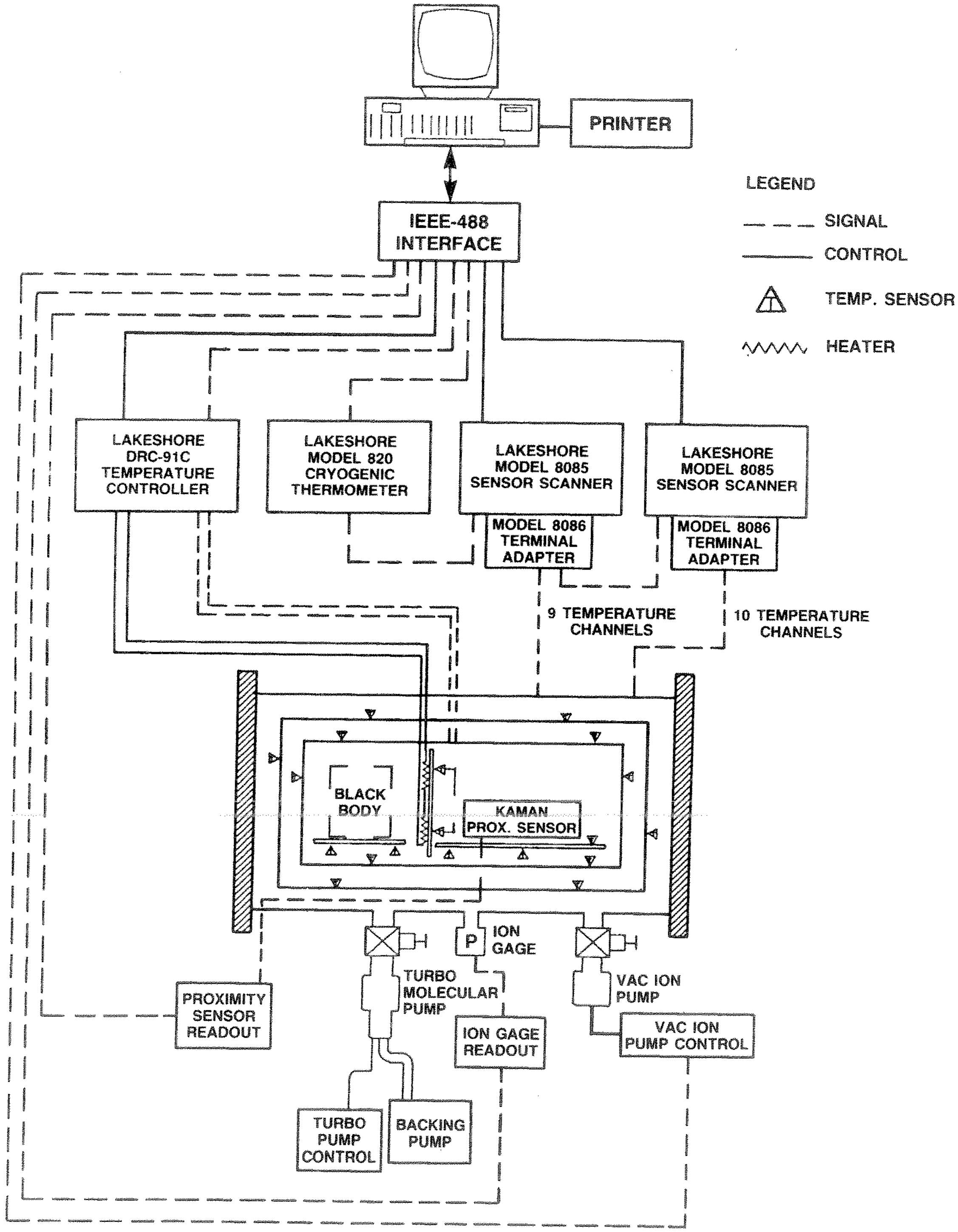


Figure 4) Schematic of the system control electronics.

densitometry which can measure optical densities over approximately 12 orders of magnitude. We are also developing sensitive amplifiers to use on solid state detectors which, given the linearity of the devices, can give measurements of transmission over 6 to 8 orders of magnitude and can serve as a cross calibration of the laser heterodyne techniques. We expect to work with the user community and develop a long term plan for the future development of calibration activity and in establishing the procedures used. This includes the development of new more sensitive absolute detectors and the possible development of spectral radiometric packages that can be circulated to test sites and returned to NBS for calibration assurance. We expect the exact nature of the effort to grow in scope and focus the next several years.

## 7. ACKNOWLEDGEMENTS

The support of the U.S. Army Strategic Defense Command for this work is gratefully acknowledged. We also wish to thank the staff of Nichols Research in Huntsville for advice and help over the course of this project.

## REFERENCES

* References made in this paper to particular brand names or specific suppliers of a service are made for ease of understanding by the reader and do not constitute an endorsement of products or service by the National Bureau of Standards over other competitive suppliers of similar products or service.

1) Vacuum cleanliness standards will be supplied to the potential user. These standards are in the process of being formulated.

2) The ACR is being constructed as a specialty item by Cambridge Research and Instrument Corporation of 21 Erie Street, Cambridge, Massachusetts 02139.

3) Compaq Computer Corporation, Houston, Texas 77070. Deskpro model 386 computers are used for the facility.

4) Kaman Instruments Corporation, 1500 Garden of the Gods Road, Colorado Springs, Colorado 80933-7463.

5) Lake Shore Cryogenics, Incorporated, 64 East Walnut Street, Westerville, Ohio 43081.